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HIGH PRECISION STEREO COMPARATOR SPECIFICATION

1.0 INTRODUCTION

The High Precision Stereo Comparator is an advanced State-of-the-Art instrument intended to provide utmost accuracy and convenience of use in the performance of stereo observations and measurements.

2.0 REFERENCE DOCUMENTS

Performance of the Comparator shall be compatible with the functional requirements of the "Development Objective, High Precision Stereo Comparator", dated 12 February 1965.

The overall configuration of the instrument, and the organization of its subsystems, shall be as described in the final engineering report of the High Precision Stereo Comparator Study, dated January 15, 1966.

3.0 GENERAL DESCRIPTION

This instrument shall consist of a high performance stereo viewing and measuring comparator capable of accepting on each of two X, Y stages roll or cut film in widths from 70 mm to 9 1/2 inches. The maximum length of roll film shall be 500 feet. The frame area available for examination and measurement on the film stages shall be no less than 9 1/2" x 20".

The comparator shall provide for the transport of roll film across each film stage such that an operator shall have a clear presentation of the imagery present upon either film stage at all times. Similarly, the operator shall have a clear and convenient presentation of imagery present on cut film placed upon either film stage. Display of this overall film format shall be so arranged that the area of the film which is observable to the operator by means of the visual observation system shall be clearly apparent at all times.

Roll film shall be transported across the film stage by means of a velocity-servo drive system which shall permit the operator to control the motion of such film while observing the imagery transported across the stage. The drive system shall permit the operator to select any desired film frame and establish its location on a comparator stage within ± 1/4 inch of the desired location with a minimum of effort.

Precise measurements of image dimensions on the comparator shall be made by means of accurate traversing of the film stage beneath the optical axis of either comparator stage. Such traverse shall be metered by a measurement system capable of recording stage motions with a precision of ± 1 part per hundred thousand in either the X or Y direction. Control over motion of the Comparator stages shall be such that either stage can be conveniently positioned under operator control to within ± 0.1 micron of the desired position.

A means of direct optical observation of stereo imagery shall be provided. This means shall consist of optical trains which provide for large variations in scale, rotation and anamorphism between conjugate images on stereo pairs. The design of the optical trains shall be equivalent to that of highest quality microscope systems and shall be oriented specifically toward preservation of image quality and clarity as required for difficult photo-interpretive purposes.

Provision shall be made for observation of any part of either film stage area in any of the following modes:

a) Direct Stereo

b) Reversed Stereo

c) Binocular observation of either stage

Scanning capability over the entire stereo area presented on both stages shall be provided without movement of the eye station.

A correlation system shall be incorporated in the High Precision Stereo Comparator which will sense discrepancies in imagery on the two comparator stages and act to cause a slaved stage to track the manually controlled master stage so that conjugate image points are kept continuously within the field of view of the optical trains.

Manual control of the film stages shall be accomplished by means of a two-axis joystick which can be selected to control the motion of either stage, or at the operator's command, shall control the motion of a selected master stage with correlation-controlled slaving of the second stage. In either case, independent control over four axes shall be attainable by the operator through the use of four handwheels, one of which shall be allocated to control of each of the axes of the two X, Y comparator stages.

Coordinate data shall be read out upon operator command. To assist in such read-out and provide protection against random miscounts, a means shall be provided by which instantaneous X and Y coordinate counts in any of the four comparator axes shall be locked in during read-out and protected against spurious counts which may affect the validity of the coordinate data.

4.0 PHYSICAL AND OPERATIONAL CONSIDERATIONS

The Stereo Comparator shall operate in a clean office environment, in which a small amount of slightly corrosive chemical fumes from photo laboratory or similar operations may be present. The following facilities shall be available at the final installation site:

a) Electricity: 110V, 1 phase and 208 V, 3 phase, 4 wire

b) Compressed air at 80 PSI

c) Vacuum

Information carrying radio frequency emissions shall be suppressed in accordance with Federal Specification 222.

5.0 DETAILED REQUIREMENTS

5.1 Overall Physical Considerations

5.1.1 The Stereo Comparator, including all components, personnel, workspace, etc. shall operate in a room 20' x 25'. During design of the prototype, consideration shall be given to reduction of required room size to 15' x 18', by use of micro-circuitry and high density electronics packaging in the operator's console and comparator cabinets.

5.1.2 The maximum size of any single component is not to exceed 47" x 95" x 80" high for shipping and installation purposes. A suitable overhead hoist shall be available at the Customer's facility to assist in installation and maintenance of massive Comparator elements.

5.1.3 The Stereo Comparator will be capable of operation in a room ambient environment as follows:

Temperature	$72^{\circ}F \pm 5^{\circ}F$
Relative Humidity	55% + 15% - 5%
Dust Particles	Less than 25 microns

If necessary, further conditioning shall be provided as part of the Stereo Comparator equipment at each comparator cabinet. Components shall be inherently invulnerable to, or protected against damage by, chemical fumes in the amounts normally found in a photo laboratory atmosphere.

5.1.4 Personnel shall be protected against hazards which may be encountered in the operation or maintenance of the equipment by means of proper design, interlocks, guards and suitable warning labels.

5.1.5 The manufacturer shall be responsible for all facility hook up from the point where the facilities enter the room. A false floor shall be provided by the customer to facilitate installation of electrical cables, air and vacuum lines in order to minimize obstructions to personnel and assist in maintaining room cleanliness.

5.1.6 Vibration isolation and leveling facilities shall be incorporated into the comparator design where necessary in order to immunize critical equipment components from adverse environmental conditions.

5.1.7 All controls required for normal operation of the Stereo Comparator after initial film loading shall be easily accessible at the operator's work station. These controls shall be arranged according to accepted [redacted] practices in order to promote rapid and accurate operation.

5.1.8 Sufficient clearance shall be provided so that the operator can raise or lower his chair height $\pm$ 2" so as to place his eye level in a comfortable position with respect to the eyelens station without being restricted by other physical considerations such as leg room.

5.2 Viewing Conditions

5.2.1 Image magnification for each stage shall be available independently at any power from 10X to 200X. This range shall be covered by means of three interchangeable objective lenses mounted in a turret, and supplemented by a zoom system which provides a magnification range of 3.5 to 1. The turret shall be indexed automatically into proper position at the operator's command, and the zoom system magnification shall be continuously variable at the operator's command. When combined with a 10X magnification at the eyelens station the ranges of magnification shall be as follows:

Objective	Zoom Lens	Overall Power
3.5X	1/3.5 → 1	10X → 35X
9X	1/3.5 → 1	26X → 90X
21X	1/3.5 → 1	60X → 209X

The optical trains shall be capable of independent or common magnification control. Independent focus control, from the operator's station, shall be available for each objective and each system.

5.2.2 Viewing shall be by microscope binocular eyepieces which shall provide for maximum operator comfort. The angular field of the eyepiece shall be greater than 35 degrees. Exit pupil, eye relief and field flatness shall be compatible with optical principles followed in modern microscope design.

5.2.3 Eyepieces shall be adjustable to provide for interpupillary distances from 50mm to 75mm, and for variations in height to suit individual operators. An adjustable headrest shall be provided for the convenience of operators during prolonged observations.

5.2.4 The tilt angle of the oculars at the eyelens station shall be adjustable within approximately ± 10 degrees, or, as an alternate, the vertical placement of the oculars shall cover a range (± 80mm) such that convenient orientation to individual operator requirements shall be provided.

5.2.5 Image quality available to the operator shall, at all magnifications, approximate that of a high performance microscope with respect to: aberration corrections, field size, field flatness, contrast and resolution. The design goal for resolution shall be eight lines per millimeter per power at 10X, decreasing linearly to five lines per millimeter per power at 200X, when measured at the center of the field of view.

5.2.6 At least 360 degrees of independent image rotation shall be available at each stage. This rotation shall not introduce dislocation or displacement with respect to the reticle.

5.2.7 A reticle dot will be inserted into each optical train immediately after the objective lens. The reticle shall be a dot of variable intensity, and its size shall be variable continuously from one-half minute of arc to four minutes of arc (at the eyelens exit pupil). The dot will be the image of a high-quality precision iris diaphragm, and it shall be demagnified sufficiently to appear as a perfect circle with a sharp edge gradient. Provision shall be made for manual adjustment of each dot position in X and Y. Since the reticle dot is to be introduced into the optical train ahead of the zoom magnification system, provision shall be made for automatic compensation of the dot image so that its apparent size does not change as the zoom system is operated.

5.2.8 An accessory anamorphic correction with a minimum ratio of 1:2 shall be provided for each optical train. Magnification and alignment of the anamorphic axis shall be adjustable independently for each optical train. The optical quality shall be compatible with the overall design objective. The accessories shall be removable easily at the operating console.

5.2.9 Each optical train shall be furnished with an adjustable high intensity illumination source to provide adequate brightness for examination of imagery with densities as high as 3.0. Design of the collecting and condensing system shall be consistent with highest optical standards to maintain image clarity and crispness at all magnifications. Provision shall be made to remove heat from the illumination source so that measurement accuracy is not impaired. Care shall be taken to insure that the apparent illumination Kelvin temperature does not fall below 3400°K under any intensity level.

5.2.10 Provision shall be made at the operator's console to provide for optical switching by reversal of the eye/object station viewing relationship (left eye to right stage and right eye to left stage), and to provide binocular monoscopic viewing of either the right or left stage.

5.3 Film Stage, Transport, and Hold-Down System

5.3.1 The Comparator shall contain two 9 1/2" by 20" film stages and accommodate formats which vary from approximately 70mm square to 9 1/2" by 20".

5.3.2 Film shall be flattened on the measurement stage by means of a vacuum hold-down system. When the film is stationary, a maximum of ten seconds, as a design objective, will be required to flatten the film to its final position. During transport of the film across the measurement stage, provision shall be made, by means of a positive-pressure air film, to protect the photographic film from scratches caused by abrasion against the film platen. After initial loading of roll film, provision shall be made for automatic pull-down, reversal of vacuum to positive pressure for transport, and subsequent re-establishment of pull-down.

5.3.3 The film hold-down system must accommodate cut (chip) film as well as roll film. When chips are cut from roll film, the width of the roll film shall be preserved so that standard width masks or detent positions which are to be developed for roll film, can be utilized.

5.3.4 It shall be possible to accomplish adjustment for various widths of roll or cut film within two minutes.

5.3.5 Design of the comparator stage and film hold-down system will be such that the Z-axis (optical axis) movement of the film plane shall be minimized during normal measurement procedures. To the extent that such movement occurs, it shall consist of smooth variations so that repeated measurements may be made in small areas (2" by 2") with a minimum necessity for refocusing the optical system.

5.3.6 The film stage system shall be capable of handling roll film which may vary in width from 70mm to 9 1/2 inches. It shall be capable of adjustment to any width within this range regardless of standard film sizes. The design of the Comparator stages which support the film transport mechanism shall be such that loading, threading and unloading of roll film can be accomplished conveniently at the front of the Comparator stage without interference from optical or mechanical elements and without risk of disturbing machine alignment during these procedures. Forward travel of the Comparator stage shall be provided to insure clearance of the film stage from obstructing comparator elements.

5.3.7 Each comparator stage shall have an independent film transport system. Each film transport system shall be motorized and provided with a variable bi-directional speed range from .5 inches per second to 50 inches per second. Direction and velocity of film transport for each stage shall be controlled by a single-axis control stick at the operator's console. Each transport system shall be designed so that proper film tension is maintained at all times. Protection against abrasions, scratches and tears shall be provided by use of edge guides and rollers throughout the film train and by use of positive air pressure to isolate film surfaces from stationary physical surfaces during transport.

5.4 Film Measurement System

5.4.1 The accuracy of the film readout measurements shall be considered to be the accuracy of measurement of a calibrated grid when it is placed on either Comparator stage and subjected to X, Y translations over the maximum 9 1/2" x 20" film format. The primary sensor of X,Y motion shall be an automatic fringecounting interferometer using a feedback-stabilized coherent light source such as a He-Ne gas laser. The fringecounts from such an interferometer shall be converted to metric values by means of a sampled-data digital multiplier. The metric equivalents of the interferometric counts which record the Comparator X,Y displacements shall be displayed to the operator and made available for punch-out. The least count of the display and punch-out system shall be no less than 0.2 micron.

5.4.2 The wavelength stability of the metering system shall be one part in 10^7 at any fixed condition within the ambient envelope. It will change with variations in ambient conditions as indicated in the following table:

Parameter	Ambient Variation	Metering Error
Temperature	$\pm$ 5^{o}F	$\pm$ 2.6 ppm
Pressure	$\pm$ 7 mm HG	$\pm$ 2.5 ppm
Humidity	$\pm$ 10% RH	$\pm$ 0.2 ppm

In addition, engine ways and measurement system reference surfaces shall be straight and orthagonal so as to introduce an error of no more than two seconds of arc in measurement between any two points within the film format area. That is, this combination shall contribute no more than $\pm$ 5 microns to a measurement over 20 inches of travel and no more than $\pm$ 2.5 microns to a measurement over 9 1/2 inches of travel. The objective of the design shall be to produce the highest practical local accuracies (over areas up to 2 inches sq.) with lesser emphasis on accuracies over longer distances.

5.4.3 The Comparator stage drives shall be capable of rapid traverse from one point to another without causing miscount or loss of accuracy. The speed of traverse shall be variable continuously under operator control. The maximum slew speed shall be 3" per second.

5.4.4 To achieve high pointing accuracy slow drive speeds shall be provided. Final pointing at highest accuracy shall be made available to the operator by means of a vernier system which incorporates a positive stepping incremental drive. The nominal step of this drive system shall be 0.1 micron with overshoot and backlash no greater than the nominal step.

5.4.5 The drive controls for both slewing and fine positioning shall provide the capability for:

a) One common control for all four axes

b) Control for both axes of either film stage

c) Independent control of either axis of either film stage by means of separate handwheels

5.5 <u>Measurement Readout System</u>

5.5.1 The coordinate position of each of the four axes shall be presented continuously to the operator on a seven digit display, plus sign if applicable. The coordinate information generating system shall also have a zero reset and preset capability.

5.5.2 In addition to the coordinate information, the following additional information shall be available as part of the readout message:

1) 10 each, eleven position rotary switches (twelve position switches with one position mechanically blocked)

2) five push-on solenoid hold and release switches and

3) sixteen push-on, push-off switches

5.5.3 On command by the operator, coordinate information and auxiliary information described in par. 5.5.2 will be readout, either into an
STAT [redacted] card punch or directly into a central computer.

5.6 Correlation Subsystem

5.6.1 The High Precision Stereo Comparator shall incorporate a flying spot scanner-photomultiplier subsystem and suitable optical components in each Comparator stage. The [redacted] sub- STAT
system will scan film image areas that approximate those observed in the optical trains. It will provide video information to a correlation system. Inclusion of the scanning system shall introduce no noticeable degradation of the optical performance of the comparator and shall be accomplished with no modification of the basic optical trains other than the introduction of beamsplitters for the insertion and removal of the scanning signal.

5.6.2 The correlation scanners shall be provided with automatically computed corrections for photographic distortion so that any combinations of the following types of photography can be intermixed on the Comparator stages:

a) Vertical Photography
b) Oblique Photography
c) Panoramic, or Scanning Photography

Such corrections shall be implemented primarily by insertion into the computer, under manual operator control, functions relating to the type of photography, geometric attitude of the camera, focal length of the camera, and altitude of the photographic vehicle. Where such functions are unknown, controls shall be provided so that the operator can approximate these computing variables by adjusting constants so as to produce visual superimposition of non-congruent imagery present on the two comparator stages. The display for observation of such superimposition shall be provided by a cathode ray tube conveniently observable at the operator's console.

5.6.3 The correlation system shall function so as to slave either Comparator stage to the other during manually controlled translations of the master stage so that conjugate image points on both stages are maintained within the operator's field of view during such translations.

5.6.4 The accuracy of the correlation system shall be such as to provide repeatability of the correlation between two photographs of ± 5 microns. On congruent photography, the superimposition of two photographs shall be within ± 5 microns of that obtained by repeated manual settings.

5.6.5 The correlation system shall be provided with a raster shaping computer which shall adjust the shape and size of the scanning raster so as to normalize the distorted geometry characteristic of non-vertical photography. The resultant video signal which describes the normalized geometry shall be available to the operator on a cathode ray tube presentation. This presentation shall serve as a supplement to the basic optical train for special cases in which the capability of distorting and enhancing video signals provides significant advantages over normal optical observation.

5.6.6 The raster shaping signals provided by the correlation system will be evaluated as possible control signals to be applied to the optical correcting elements (image rotation, zoom magnification, and anamorphic accessory) so that the correlation system can provide a first-order correction to maintain stereo fusion of non-congruent imagery through the basic optical train. Design of the drive systems for these optical corrections shall provide for retrofit of these units to incorporate this capability.

5.7 Overall Format Display

5.7.1 Provision shall be made in the Stereo Comparator for convenient display to the operator of the entire imagery present on both film stages. This display shall also provide a convenient means for locating the areas within the overall format which is observable in the optical train at any time.

5.7.2 A previewing station shall be provided at each Comparator stage for the purpose of recording within an erasable memory the imagery contained on roll film. Such imagery shall be recorded automatically prior to advance of the roll film onto the measurement stage. Since film advance is asynchronous, at a rate controlled entirely by the operator, provision shall be made for buffer storage between the film recording equipment and the synchronous video storage medium. Therefore, a metering roller shall measure the advance of the film at a point prior to its entry onto the measurement area. At predetermined intervals of approximately one inch of film travel the metering roller shall activate a flash tube which shall cause the imagery on the length of film to be recorded in the photocathode of a vidicon tube.

5.7.3 Immediately after recording of film imagery on the vidicon photocathode, timing and logic circuitry shall monitor the position of a video disc recording system and cause a readout of the information into this video recording mechanism. Subsequent repetitive readout of this information shall be controlled by the film-advance measurement roller so that the information readout is presented to the operator on a cathode ray tube for each comparator stage in synchronism with the motion of the film across the appropriate film stage.

5.7.4 Display of overall format film imagery will be at a resolution, contrast, and acuity level which is consistent with that of high quality closed circuit television systems. It shall provide for resolution of a standard 800 line TV resolution target.

5.7.5 Movement of the film beneath the optical axis of either comparator stage shall be reflected in corresponding movement of X and Y crosshairs across the face of the CRT which displays the overall film format, so that the operator shall have, at all times, a convenient guide to location of the film stage with respect to the Comparator optical axis.

5.7.6 An auxiliary input channel shall be provided so that imagery on cut film can be recorded and displayed for overall format viewing and point location. This auxiliary input channel shall consist of a fixed platen on which the cut film chip can be placed for scanning by a separate closed-circuit TV camera. Information presented to this TV camera shall be stored in the format display video recording system so that when the film chip is placed on a comparator stage in a position which corresponds to that used for recording, the point location crosshairs (described in Section 5.7.5) shall serve as an accurate reference to the point of observation located under the Comparator optical axis.

5.8 Control Console

5.8.1 Controls shall be grouped functionally and within convenient reach at the operator's console. The arrangement of controls shall
STATINTL be based on a [redacted] task analysis to facilitate rapid and accurate operation of the instrument.

5.8.2 A work space shall be provided for the operator, convenient to his normal writing position. A portion of this area shall consist of a light table with variable illumination.

5.9 Reliability and Service Time

5.9.1 The Comparator and related equipment shall be designed to withstand operating service usage, under normal operating conditions, for a period of 5000 cumulative operational hours without degradation of performance, with only minor maintenance due to normal mortality of expendable replacement parts.

5.9.2 To insure maximum up-time a preventive maintenance program is to be established utilizing Government maintenance personnel where possible.

5.10 Security

5.10.1 Design consideration shall be given to reducing the probability of detection of security information which may be emitted by mechanical, electro-mechanical or electronic means. There shall be no mechanical or electronic radiation detectable beyond 150 feet from the instrument.

5.11 Test Provisions

5.11.1 The contractor shall prepare and submit to the project monitor for approval a detailed test plan sixty days prior to completion of the instrument. This test plan shall specify and describe in detail those tests to be conducted both at the contractor's plant and the Government facility to determine conformance with requirements.

5.11.2 The contractor shall provide all test targets, test film and test equipment to adequately demonstrate fulfillment of performance requirements and provide the Government with a calibration report. All test materials and equipment shall be detailed in the test plan submitted for approval.

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